

CLAIMS

What is claimed is:

1. A reactor for producing alkenes from alkanes, comprising:
 - a first reaction zone comprising a catalytic bed, wherein the first reaction zone is operated at conditions sufficient to generate heat by the combustion of a fuel;
 - a first feed inlet connected to one end of the first reaction zone, wherein the first reaction zone feed inlet is suitable for introducing a first reaction zone feed comprising the fuel and an oxygen-containing gas to the first reaction zone;
 - a first reaction zone outlet connected to another end of the first reaction zone, wherein the first reaction zone outlet is suitable for passing a first reaction zone effluent;
 - a second reaction zone comprising a heating zone, wherein the heating zone is in thermal contact with the first reaction zone to allow at least a fraction of the heat generated in the first reaction zone to be transferred to the second reaction zone, wherein the second reaction zone is operated at conditions sufficient to generate an alkene product;
 - an alkane feed inlet connected to the heating zone of the second reaction zone, wherein the alkane feed inlet is suitable for introducing an alkane feed to the heating zone; and
 - a second reaction zone outlet connected to another end of the second reaction zone, wherein the second reaction zone outlet is suitable for passing a second reaction zone effluent comprising the alkene product.
2. The reactor of claim 1, wherein the reactor is a short contact time reactor.
3. The reactor of claim 1, wherein the reactor further comprises at least one feed preheater.

4. The reactor of claim 3, wherein the at least one feed preheater heats the first reaction zone feed to temperatures up to about 600 °C.
5. The reactor of claim 3, wherein the at least one feed preheater heats the first reaction zone feed to temperatures from about 200°C to about 400°C.
6. The reactor of claim 1, wherein the catalytic bed in the first reaction zone comprises platinum, palladium, rhodium, ruthenium, iridium, osmium, chromium, or combinations thereof.
7. The reactor of claim 1, wherein the catalytic bed in the first reaction zone comprises platinum, palladium, chromium, or combinations thereof.
8. The reactor of claim 1, wherein the first reaction zone has a reaction temperature of from about 200 °C to about 1,000 °C.
9. The reactor of claim 1, wherein the first reaction zone effluent comprises substantially no oxygen.
10. The reactor of claim 1, wherein the second reaction zone includes a catalyst comprising a metal from the group consisting of Groups 2, 4-7, 11-15 metals of the Periodic Table of the Elements, scandium, yttrium, actinium, iron, cobalt, nickel, oxides of any such metals, or combinations thereof.

11. The reactor of claim 10, wherein the catalyst in the second reaction zone further comprises at least one metal from Groups 8, 9, and 10 of the Periodic Table of the Elements.
12. The reactor of claim 1, wherein the second reaction zone includes an inorganic refractory oxide.
13. The reactor of claim 1, wherein the second reaction zone is substantially free of catalytic metal.
14. The reactor of claim 1, wherein the second reaction zone has a reaction temperature of from about 600 °C to about 1,200 °C.
15. The reactor of claim 1, wherein the catalytic bed in the first reaction zone comprises a diluted catalytic bed comprising a catalyst and a diluent material.
16. The reactor of claim 15, wherein the diluent material comprises a refractory oxide.
17. The reactor of claim 15, wherein the catalyst in the first reaction zone comprises a support material, and wherein the diluent material comprises the same support material.
18. The reactor of claim 1, wherein the alkane feed inlet is further suitable for delivering an oxygen-containing gas to the heating zone of the second reaction zone.

19. The reactor of claim 1, further comprising an oxygen inlet suitable for delivering a supplemental oxygen-containing feed to the second reaction zone.

20. The reactor of claim 1, wherein the second reaction zone is downstream of the first reaction zone, and wherein the first reaction zone outlet is in fluid communication with the second reaction zone so as to pass at least a portion of the first reaction zone effluent to the second reaction zone.

21. A process for the production of alkenes from alkanes, comprising:

(A) feeding a first zone feed to a first reaction zone having a combustion catalyst, wherein the first zone feed comprises an oxygen-containing gas and a fuel;

(B) contacting the first zone feed with the combustion catalyst under conditions sufficient to combust at least a portion of the fuel so as to form a first reaction zone effluent having less than about 1,000 ppm oxygen;

(C) feeding the combustion zone effluent to a second reaction zone;

(D) introducing an oxygen-containing feed and an alkane feed to the second reaction zone; and

(E) reacting at least a portion of the alkane feed with oxygen in the second reaction zone at conditions sufficient to form an alkene product.

22. The process of claim 21, wherein the fuel comprises hydrogen, carbon monoxide, C1-C4 alkanes, C1-C4 alkenes, naphtha, natural gas, syngas, or mixtures thereof.

23. The process of claim 22, wherein the first zone feed has a molar O₂:C ratio less than 2:1.

24. The process of claim 21, wherein the fuel comprises carbon monoxide.
25. The process of claim 24, wherein the first zone feed has a molar $O_2:C$ ratio less than 1:2.
26. The process of claim 21, wherein step (A) further comprises preheating the first zone feed prior to feeding the first zone feed to the first reaction zone.
27. The process of claim 21, wherein the conditions sufficient of step (B) include temperatures of from about 200° C to about 1,000° C.
28. The process of claim 21, wherein the combustion catalyst comprises platinum, palladium, rhodium, ruthenium, iridium, osmium, chromium, or combinations thereof.
29. The process of claim 21, wherein the combustion catalyst comprises platinum, palladium, chromium, or combinations thereof.
30. The process of claim 21, wherein the first reaction zone comprises a diluted catalytic bed comprising the combustion catalyst and a diluent material.
31. The process of claim 30, wherein the diluent material comprises a refractory oxide.
32. The process of claim 21, wherein the first reaction zone effluent is substantially free of molecular oxygen.

33. The process of claim 21, wherein the second reaction zone comprises an inorganic oxide, and is substantially free of catalytic metal.
34. The process of claim 21, wherein the second reaction zone excludes a catalyst.
35. The process of claim 21, wherein the second reaction zone includes a catalyst comprising a metal from the group consisting of Groups 2, 4-7, 11-15 metals of the Periodic Table of the Elements, scandium, yttrium, actinium, iron, cobalt, nickel, oxides of any such metals, and combinations thereof.
36. The process of claim 21, wherein the alkane feed and the oxygen-containing feed are mixed prior to being introduced in step (D) to the second reaction zone.
37. The process of claim 21, wherein the alkane feed comprises ethane.
38. The process of claim 21, wherein the alkane feed further comprises oxygen.
39. The process of claim 38, wherein the alkane feed comprises an alkane to oxygen ratio of from about 1.6:1 to about 10:1.
40. The process of claim 21, wherein the conditions sufficient of step (E) include temperatures from about 600° C to about 1,200° C.

41. The process of claim 21, wherein the process comprises an alkane conversion of at least about 60 percent, and an alkene selectivity of at least about 50 percent.

42. The process of claim 21, wherein the second reaction zone comprises a heating zone in thermal contact with the first reaction zone, and wherein step (D) further comprises heating the alkane feed through the heating zone by heat transfer from the first reaction zone to the heating zone.

43. The process of claim 42, wherein the alkane feed and the oxygen-containing feed are introduced separately, and the oxygen-containing feed is introduced to the second reaction zone without passing through the heating zone.

44. A process for the production of alkenes from alkanes, comprising:

(A) feeding a first zone feed to a first reaction zone having a combustion catalyst, wherein the first zone feed comprises an oxygen-containing gas and a fuel;

(B) contacting the first zone feed with the combustion catalyst under conditions sufficient to combust at least a portion of the fuel so as to produce heat and a combustion zone effluent;

(C) feeding an alkane feed to a second reaction zone, wherein at least a portion of the second reaction zone is in thermal contact with the first reaction zone, and wherein the alkane feed absorbs a sufficient amount of the heat produced in the first reaction zone to initiate the conversion of at least one alkane to an alkene in the second reaction zone; and

(D) converting at least a portion of the alkane feed so as to form an alkene product.

45. The process of claim 44, wherein the fuel comprises hydrogen, carbon monoxide, C1-C4 alkanes, C1-C4 alkenes, naphtha, natural gas, syngas, or mixtures thereof.
46. The process of claim 44, wherein the alkane feed comprises ethane, and wherein the alkene product comprises ethylene.
47. The process of claim 44, wherein the alkane feed further comprises an oxygen-containing gas.
48. The process of claim 47, wherein the alkane feed comprises an alkane to oxygen ratio of from about 1.6:1 to about 10:1.
49. A process for the production of alkenes from alkanes, comprising:
- (A) feeding a first zone feed to a first reaction zone having a combustion catalyst, wherein the first zone feed comprises an oxygen-containing gas and a fuel;
 - (B) contacting the first zone feed with the combustion catalyst under conditions sufficient to combust at least a portion of the fuel so as to form a first reaction zone effluent containing at least 1,000 ppm oxygen;
 - (C) providing an alkene production zone comprising a heating zone in thermal contact with the first reaction zone, wherein the alkene production zone is substantially free of catalytic metal;
 - (D) passing the first reaction zone effluent to the alkene production zone;
 - (E) introducing an alkane feed to the alkene production zone;

(F) heating the alkane feed through the heating zone by heat transfer from the first reaction zone to the heating zone; and

(G) reacting at least a portion of the alkane feed with oxygen in the alkene production zone at conditions sufficient to form an alkene product.

50. The process of claim 49, wherein the fuel comprises hydrogen, carbon monoxide, C1-C4 alkanes, C1-C4 alkenes, naphtha, natural gas, syngas, or mixtures thereof.

51. The process of claim 50, wherein the first zone feed has a molar O₂:C ratio less than 2:1.

52. The process of claim 49, wherein the fuel comprises carbon monoxide.

53. The process of claim 52, wherein the first zone feed has a molar O₂:C ratio less than 1:2.

54. The process of claim 49, wherein step (A) further comprises preheating the first zone feed prior to feeding the first zone feed to the first reaction zone.

55. The process of claim 49, wherein the conditions sufficient of step (B) include temperatures of from about 200° C to about 1,000° C.

56. The process of claim 49, wherein the combustion catalyst comprises platinum, palladium, chromium, or combinations thereof.

57. The process of claim 49, wherein the first reaction zone comprises a diluted catalytic bed comprising the combustion catalyst and a diluent material.
58. The process of claim 57, wherein the diluent material comprises a refractory oxide.
59. The process of claim 57, wherein the diluted catalytic bed comprises a diluent material-to-catalyst weight ratio between about 1:2 and about 10:1.
60. The process of claim 49, wherein the alkene production zone comprises an inorganic oxide.
61. The process of claim 49, wherein the alkane feed comprises ethane, and the alkene product comprises ethylene.
62. The process of claim 49, wherein the alkane feed further comprises oxygen.
63. The process of claim 62, wherein the alkane feed comprises an alkane to oxygen ratio of from about 1.6:1 to about 10:1.
64. The process of claim 49, wherein the conditions sufficient of step (G) include temperatures from about 600° C to about 1,200° C.
65. The process of claim 49, wherein the process comprises an alkane conversion of at least about 60 percent, and an alkene selectivity of at least about 50 percent.

66. The process of claim 49, further comprising introducing a supplemental oxygen feed to the alkene production zone without passing it through the heating zone.